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THE POTENTIAL OF PINEAPPLE ROTATIONS TO IMPROVE CHEMICAL PROPERTIES OF ULTISOLS

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Abstract

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Planting pineapple monoculture and continuously can decrease the nutrient availability of Ultisols. Crop rotation is potential to solve the problem of nutrient availability. The aim of the research is to study the potential of pineapple rotation with cassava and King grass in improving chemical properties of Ultisols. The study was conducted in pineapple plantation of Great Giant Pineapple Company, Lampung, Indonesia using a survey method in three types of pineapple rotation: pineapple without a rotation basis (P-P), pineapple rotation with cassava (P-C), and pineapple rotation with King grass (P-K). Soil sampling at depth 0-30 cm and each location are taken 5 points as replication. Chemical characteristic observed include carbon organic, exchangeable Al, soil pH, total nitrogen, available P and K. The result showed that P-C and P-K could increase carbon organic, soil pH, nutrient availability and also decreased exchangeable Al. P-K showed the better potential in improving chemical properties of Ultisols. It increasing carbon organic, soil pH, total nitrogen, available P and K respectively up to 1.56%; 4.92; 1.18 g kg^{-1}; 8.18 mg kg^{-1}; 223.2 mg kg^{-1} and also decreasing exchangeable Al up to 0.52 $cmol_c$/kg. P-K is potential to increase pineapple productivity.

Key words: pineapple; crop rotation; soil chemical; properties

Introduction

Pineapple is widely cultivated in Ultisols. Some chemical properties of Ultisols are low pH, high Al, Fe and Mn saturation, low base saturation and low organic matter content (Prasetyo et al., 2001). Great Giant Pineapple Company is one of largest pineapple plantation companies in Indonesia with total area width of 32 000 hectares (Rahmat et al., 2013). Planting pineapple monoculture and continuously in Ultisols had an adverse impact on soil include: degrading soil fertility, increasing pest and plant diseases (Liu et al., 2006; Xiong et al., 2015) and decreasing soil organic content (Martinez et al., 2004; Zhong et al., 2014). The decreasing soil organic content had a negative impact on physical, chemical and biological properties (Esmaeilzadeh and Ahanggar, 2014). The significant role of soil organic matter in physical, chemical and biological properties include increasing soil pH, cation exchange capacity, nutrient availability, water holding capacity, and improving population and activity of soil microorganism (Ibeawuchi et al., 2015; Fageria, 2012; Chauhan et al., 2014).

Crop rotation is an alternative to increasing soil organic content, improve soil structure and soil quality (Liu et al., 2006; Ball et al., 2005). Crop rotation is more efficient to increase the yield compared monoculture system and also can improve soil productivity (Varvel 2000; Nevens and Reheul, 2001). Crop rotation plays a significant impact on soil health include: increasing plant nutrient and water use efficiency and disrupting pest and plant disease life cycles (Carter et al., 2003).

However, there is not much research or information related to the potential of pineapple rotation with various plants in improving soil fertility, especially on Ultisols. Pineapple rotation with King grass is possible to improve soil fertility

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caused the grassland system can increase soil organic content and nutrient availability (Rumpel et al., 2015). According to Geren and Kavut (2015), King grass is a fast growing plant and can adaptation on varieties of land condition. Grass cultivation had a real impact on the environment and becomes a problem solution of agriculture productivity (Nan, 2004). Meanwhile, pineapple rotation with cassava also can be an alternative. Cassava has big potential to be food, feed, and raw material of bioindustry (Echebirir dan Edaba, 2008). Cassava is essay adaptation in a various agroecological condition such as dry climate and marginal land (El-Sharkawy, 2012).

The aim of the research is to study the potential of pineapple rotation with cassava and King grass on improving soil chemical properties of Ultisols, especially on the content of organic carbon, exchangeable Al, soil pH and nutrient availability.

Material and Methods

Study Area

The research was conducted in pineapple plantation of Great Giant Pineapple Company, Lampung, Indonesia (4° 49′23.1″ S 105°16′06.3″ E) (Figure1). Location at an altitude 32 m above sea level, the elevation is between 0-2%, the annual rainfall during last 30 years is 2394.24 ± 485.936 mm year^{-1}. The soil types of location is Ultisols with pH between 4.19 – 4.93, organic carbon 0.71 – 1.16%, exchangeable Al 0.55 – 2.04 cmol$_c$/kg, total soil nitrogen 0.80 – 1.10 g kg^{-1}, available P 5.82 – 11.94 mg kg^{-1}, K 26.90 – 369.93 mg kg^{-1}, Ca 23.47 – 164.58 mg kg^{-1}, Mg 3.66 – 67.39 mg kg^{-1}, Na 6.66 – 12.90 mg kg^{-1}, Base Saturation 19.63 – 30.22%, Cation Exchange Capacity (CEC) 2.35 – 2.88 cmol$_c$/kg (Table 1).

Table 1
Soil chemical characteristic of Ultisol in Lampung

pH H_2O	4.19 – 4.93
pH KCl	3.62 – 4.10
Organic Carbon (%)	0.71 – 1.16
Exchangable Al (cmol$_c$/kg)	0.55 – 2.04
Total Nitrogen (g kg^{-1})	0.80 – 1.10
P (mg kg^{-1})	5.82 – 11.94
K (mg kg^{-1})	26.9 – 369.93
Ca (mg kg^{-1})	23.47 – 164.58
Mg (mg kg^{-1})	3.66 – 67.39
Na (mg kg^{-1})	6.66 – 12. 90
Base Saturation (%)	19.63 – 30.22
CEC (cmol$_c$/kg)	2.35 – 2.88

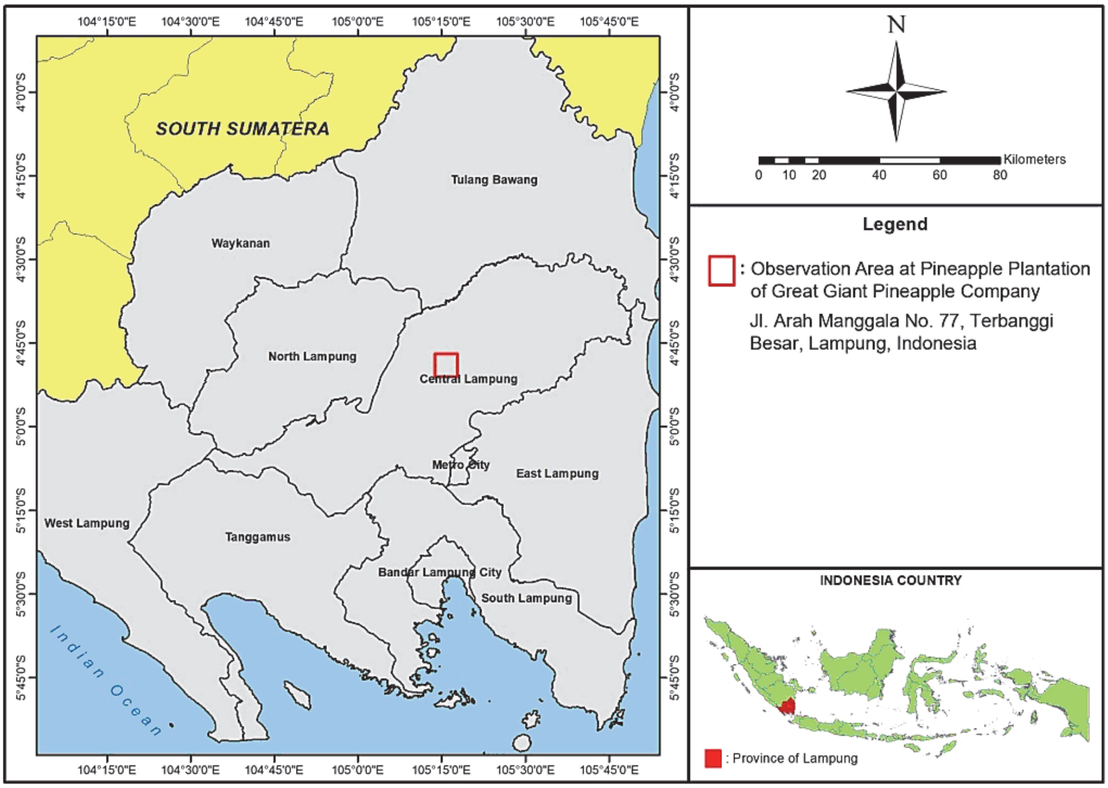

Fig. 1. Map of observation area

Soil Sampling and Laboratory Analysis

The Research using survey method in three types of pineapple rotation: pineapple without a rotating basis (P-P), pineapple rotation with cassava (P-C), and pineapple rotation with King grass (P-K). P-P is continuously pineapple monoculture system and fruit harvested on 18 month age. When harvesting, only its fruit is taken, and the plant allowed to re-growth. P-C is cultivation cassava after pineapple harvesting. The growing time of cassava is ten months, after that followed by pineapple replanting. P-K is farming King grass after pineapple crop. The King grass is allowed to grow for 24 months, and once every three months the pruning is done. During pruning, there are many grass residues left in the soil. Those all three types of rotation are applied 25 ton ha^{-1} of cow dung compost before planting. Particularly on P-C and P-K, five tons of pineapple plant residue also incorporate when soil retillage before planting. Pineapple compost contains 678.6 g kg^{-1} organic matter, 10.75 g kg^{-1} total nitrogen, 0.83 g kg^{-1} P_2O_5 and 11.4 g kg^{-1} K_2O (Liu et al., 2013).

Soil samples collected from a depth of 0-30 cm. At each site, soil samples taken at five different points as replicates, so there were 15 soil samples.

Laboratory analysis was conducted in Central Laboratory of Great Giant Pineapple Company, Lampung, Indonesia, and Soil Chemical and Fertility Laboratory, Faculty of Agriculture, Sebelas Maret University. Before analyzed, soil samples were air dried, sieved through 2 mm and 0.5 mm size. Parameters observed include organic carbon, exchangeable Al, soil pH, total soil Nitrogen, available P and K. Measurement of organic carbon using Walkley-Black method, exchangeable Al (HCl titration method), and soil pH H_2O and KCl (1:2.5 ratio of soil: water). Total nitrogen was determined by the Kjeldahl method, available P (Bray 1 method), while available K was determined by flame foto meter and ammonium acetate saturated method (Tan, 2005).

Statistics Analysis

The comparison of chemical properties between locations was analyzed using T-test, while the correlation between parameters using Pearson's correlation test with SPSS 16 software (Abua et al., 2016).

Results and Discussion

Rotation effect on organic carbon

Organic carbon reflects the content of soil organic matter, and it is essential for water holding, supplying and retaining nutrients (Grigal, 2000). Pineapple rotation could increase soil organic carbon significantly ($p < 0.05$). Organic carbon was higher in P-C and P-K than P-P (Table 2). The values of organic carbon are 1.39%, 1.56%, dan 0.99% respectively for P-C, P-K, and P-P. The addition of pineapple biomass chopping that given at the beginning of soil tillage in rotation system is thought to increase soil organic carbon. Liu et al., (2013) reported that the pineapple plant biomass contains 232 g kg^{-1} organic matter and it will increase soil organic carbon when applied in soil. Meanwhile, organic carbon was higher in P-K than P-C (Table 2). That might be due to the contributions of the litter remains or litter fall at the time of pruning once in 3 months, and some of the dead grass roots during the growth phase. Plant residues in the soil will be decomposed by the microbe and can increase soil organic carbon (Xu et al., 2006; Aminiyan et al., 2016). Besides that, the grass had a dense root system so that the dead roots can be the source of carbon in the soil (Zhou et al., 2012).

Rotation effect on exchangeable Al

The acid soil contained exchangeable Al (Prasetyo et al., 2001) as one of the limiting factors in agricultural production (Abreu et al., 2003). Rotation of P-K could decrease exchangeable Al significantly ($p < 0.05$), and there is no significantly different between P-C and P-P ($p > 0.05$). Exchangeable Al was lowest in P-K (0.52 $cmol_c$/kg), followed by P-C (1.75 $cmol_c$/kg) and P-P (1.83 $cmol_c$/kg) (Table 2).

Decreasing of exchangeable Al was negatively correlated ($r = -0.67$) with the increasing of soil organic carbon (Figure 2). The decomposition product of organic residues in P-K

Table 2
Chemical properties of soil in the location observed

Parameters	Pineapple-Pineapple (P-P)	Pineapple-Cassava (P-C)	Pineapple-King Grass (P-K)
Organic Carbon (%)	0.99 ± 0.0.12 a	1.39 ± 0.06 b	1.56 ± 0.14 c
Exchangeable Al ($cmol_c$/kg)	1.83 ± 0.14 b	1.75 ± 0.15 b	0.52 ± 0.11 a
pH H_2O	4.30 ± 0.09 a	4.54 ± 0.06 b	4.92 ± 0.06 c
pH KCl	3.85 ± 0.12 a	4.04 ± 0.09 b	4.48 ± 0.11 c
Available P (mg kg^{-1})	5.13 ± 0.67 b	4.14 ± 0.30 a	8.48 ± 1.22 c
Total Nitrogen (g kg^{-1})	0.97 ± 0.05 a	1.10 ± 0.04 b	1.18 ± 0.07 b
Available K(mg kg^{-1})	64.49 ± 13.20 a	111.81 ± 23.96 b	223.20 ± 29.58 c

Note: The average value in the same row followed by the same letters shows not significantly difference in T-test at the confidence interval of 95%

and P-C release of organic acid forms a chelate with exchangeable Al. Organic acids were detected during decomposition of organic matter (Kumari et al., 2008). Application organic acid to soil can decrease exchangeable Al and increase soil pH (Yang et al., 2013; Winarso and Taufiq, 2011). Meanwhile, the lowest exchangeable Al in P-K might be due to the compact rooting system of grass that produces root exudates such as organic acid. Some plant types can secrete organic acids such as fulvic acid, citrate acid, and oxalate acid than can chelate toxic substance such as Al (Schoettelndreier, 2001; Azura et al., 2011; Keshav et al., 2013).

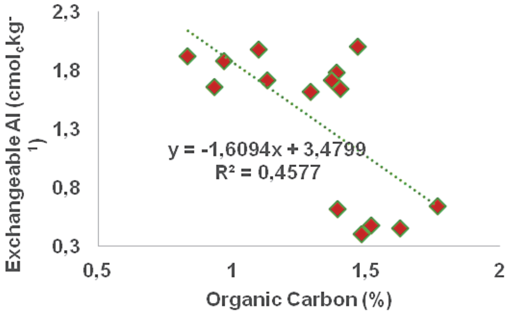

Fig. 2. Correlation between organic carbon and exchangeable Al (n = 15)

Rotation effect on soil pH

Soil pH is an indication of the acidity or alkalinity of soil and affects physical, chemical and biological soil properties (Moht-Aizat et al., 2014). Crop rotation could increase soil pH significantly ($p < 0.05$). Soil pH was highest in P-K (4.92), and significantly different with P-C (4.52) and P-P (4.30), whereas pH KCl is 4.48, 4.04, and 3.85, respectively (Table 2). The increase of soil pH negatively correlated (r = -0.92) with the decreased of exchangeable Al (Figure 3). Al fixation by organic acid from organic matter decomposition and grass root exudate affect the increase of soil pH. Al is a major supplier H^+ ion in acid soil which makes low soil pH (Winarso and Taufiq, 2011). Organic acid in acid soil would chelate source of soil acidities such as Al and Fe thereby increasing soil pH (Drouillon and Merckx, 2003; Tsado et al., 2014; Desta, 2015).

Rotation effect on available P

Available P is a significant limiting factor for crop production on acid soil especially Ultisols due to high P fixation by Al and Fe (Hoberg et al., 2005). Rotation of P-K could increase available P significantly ($p < 0.05$), but P-C rotation decreased it significantly ($p < 0.05$). The available P was highest in P-K (8.48 mg kg^{-1}) while in P-C is the lowest (4.14 mg kg^{-1}) (Table 2). The increased of available P was positively correlated (r = 0.79) with increased soil pH (Figure 4). Al is a major supplier H^+ ion in the acid soil which makes low soil pH (Winarso dan Taufiq, 2011). Besides that, Al and Fe strongly absorb P as Al and Fe-phosphate (Abolfazli et al., 2012). The secretion of organic acids from organic matter decomposition and root grass exudate was the primary mechanism for enhancing soil pH and soil available P (Tsado et al., 2014; Desta, 2015). Yang et al. (2013) reported that addition of organic acid to soil affect decreasing Al content followed by improving phosphorus availability. Cultivation of Congo grass increased available P due to decreasing P fixation by root exudates (Rosolem et al., 2014). Meanwhile, the lower available P in P-C is due to significant absorption of P by cassava thereby decreasing available P in soil. Cassava needs an enormous amount of P to create the root tubers (Ispandi, 2003). Howeler (2002) suggests that cassava needs 13.6 kg ha^{-1} P to grow optimally until harvest.

Rotation effect on total nitrogen

Plant growth needs nitrogen in significant amount (Lupi

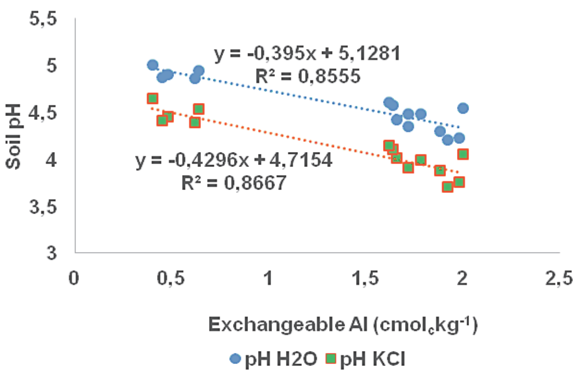

Fig. 3. Correlation between exchangeable Al and soil pH (n = 15)

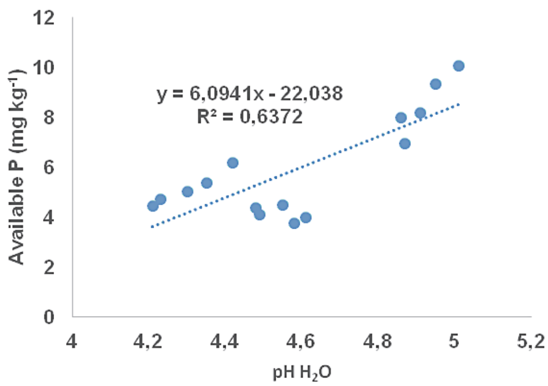

Fig. 4. Correlation between soil pH and available P (n = 15)

et al., 2013). Pineapple rotation could increase total soil nitrogen significantly ($p < 0.05$). Total nitrogen was the highest in P-K (1.18 g kg^{-1}), followed by P-C (1.10 g kg^{-1}), and P-P was the lowest (0.97 g kg^{-1}) (Table 2). The increasing of total soil nitrogen positively correlated (r = 0.83) with the increasing of soil organic carbon (Figure 5). Total soil nitrogen is determined by the amount and conditions of soil organic matter (Anggria et al., 2012). Pineapple plant biomass, grass residues and the dead roots of grass contribute the soil organic carbon thus increase total soil nitrogen (Kaleeem-Abbasi et al., 2015). Organic matter decomposed by soil microorganism to converse organic nitrogen (protein and amino acids) to inorganic (NH_4^+ dan NO_3^-) that available to be absorbed by the plant (Wijanarko, 2015; Usman et al., 2016). Meanwhile, the highest total soil nitrogen in P-K is affected by the compact rooting system of grass is thought to be a good medium for benefit soil microorganism (Huang et al., 2014). Azotobacter sp. is one of free nitrogen fixers that life in the rhizosphere and helps to increase soil nitrogen (Jnawali et al., 2015).

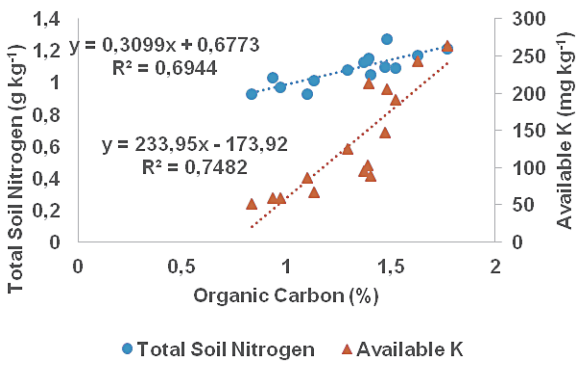

Fig. 5. Correlation between organic carbon with total soil nitrogen and available K (n = 15)

Rotation effect on available K

The leaching of plant nutrients such as nitrogen and potassium is a major problem in agricultural management (Wagner de Oliveira et al., 2002). Pineapple rotation could increase available K significantly ($p < 0.05$). The available K from the highest to the lowest was P-K (223.20 mg kg^{-1}), P-C (111.81 mg kg^{-1}), and P-P (64.49 mg kg^{-1}), respectively (Table 2). The increasing of available K positively correlated (r = 0.86) with increasing soil organic carbon (Figure 5). Soil organic matter is the supplier of soil nutrients (Grigal, 2000). The decomposition of soil organic matter would release soil nutrient such as N, P, K (Fageria, 2012). The highest available K in P-K related with compact root grass system as the substrate for K solubilizing soil microorganism associated with the abundant amount of organic acids (Wang et al., 2000). The existence of soil solubilizing microorganism in rhizosphere can help release K (Lian et al., 2008).

Conclusion

Pineapple rotation with King grass showed the highest increase N, P, K availability than the rotation with cassava and without a rotating basis. The increasing soil macronutrients availability related with decreasing of exchangeable Al and increasing of soil organic C and pH. Rotation of pineapple with King grass recommends as an alternative pineapple cropping system to improve soil chemical properties in Ultisols.

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